Elevation Bearing Maximum Load, 70-Meter Antenna

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The elevation bearing loads of the 70-m antenna are presented and shown to be within the bearing safe loading limits.

I. Introduction

One of the preliminary frequency analyses of the 64-m antenna disclosed that considerable flexibility was attributable to the structure adjacent to the elevation bearings. In order to reduce this compliance, this adjacent structure and the bearings were made substantially larger. The result is that the stresses in these parts are small when used with the 64-m reflector and will remain sufficiently small when used with the larger 70-m reflector, which has an extended one-meter noise shield at its outer edge. This report serves to document the loads on the elevation bearings of the larger 70-m reflector and to compare these loads to the corresponding ones of the 64-m antenna.

II. Design Description

The antenna elevation axis bearings are composed of two trunnion assemblies attached to the antenna tipping structure, four spherical roller bearings, and four bearing housings attached to the alidade. Each trunnion assembly is composed of a large steel casting (JPL Dwg. 9437476) having a forged steel shaft (JPL Dwg. 9435754) pressed into it. The centers of these trunnions are spaced 17.07-m (672 in.) apart, and the two spherical roller bearings at each trunnion assembly are symmetrically spaced 0.914 m (36 in.) from the trunnion centerline. Figures 1 and 2 show the general arrangement of the principal structural elements of the bearing installation. Appropriate seals, bearing retainers, etc. are not shown in these figures but are shown on JPL Dwgs. 9436183 and 9437997.

III. Bearing Maximum Loads

The loads on the elevation bearing assemblies are caused by the weight of the antenna tipping structure and by the wind loading acting on this structure.[1] The maximum radial load acting on one trunnion assembly, F_R, is given by the following equation, where the numerical subscripts 64 and 72 identify the antenna size:

$$F_{R_{64}} = \left\{ \left[\frac{W_T}{2} + q\frac{\pi}{4}D^2\,(0.345) \right]^2 + \left[q\frac{\pi}{4}D^2\,(0.451) \right]^2 \right\}^{1/2} \tag{1}$$

[1]The wind loading is derived in Appendix III and summarized in Table VI of *The Effects of Wind Loading on the Bearings and Drives of the 64-m and 70-m Antennas* (unpublished), H. McGinness, 1984, Reorder No. 84-2, Jet Propulsion Laboratory, Pasadena, Calif.

$$F_{R_{72}} = \left\{ \left[\frac{W_T}{2} + q\frac{\pi}{4}D^2\,(0.332) \right]^2 + \left[q\frac{\pi}{4}D^2\,(0.439) \right]^2 \right\}^{1/2} \quad (2)$$

The axial load on one trunnion assembly, F_A, is equal to half the side force load on the antenna, and for either the 64- or 72-m antenna is:

$$F_A = 0.144\,q\frac{\pi}{4}D^2 \quad (3)$$

where

W_T = the total weight of the antenna tipping structure

q = the dynamic pressure of the wind

D = the antenna dish diameter

The dimensionless numerical coefficients in Eqs. (1), (2), and (3) correspond to antenna elevation and azimuth angles of 60° each. This antenna attitude produces the maximum bearing loads.

Since there are two bearings per trunnion assembly, the radial and axial loads per bearing are less than that given by Eqs. (1), (2), and (3) but could be more than half of the amount. It will be assumed that the maximum load per bearing is 2/3 the total amount. These maximum bearing loads P_R and P_A are:

$$P_{R_{64}} = \frac{2}{3}\left\{ \left[\frac{W_{64}}{2} + q\frac{\pi}{4}D_{64}^2\,(0.345) \right]^2 + \left[q\frac{\pi}{4}D_{64}^2\,(0.451) \right]^2 \right\}^{1/2} \quad (4)$$

$$P_{R_{72}} = \frac{2}{3}\left\{ \left[\frac{W_{72}}{2} + q\frac{\pi}{4}D_{72}^2\,(0.332) \right]^2 + \left[q\frac{\pi}{4}D_{72}^2\,(0.439) \right]^2 \right\}^{1/2} \quad (5)$$

$$P_A = \frac{2}{3}\left[0.144\,q\frac{\pi}{4}\,D^2 \right] \quad (6)$$

The tipping structure estimated weights for the 64- and 70-m diameter antennas are 11,991,800 N (2,696,000 lb) and 16,439,800 N (3,696,000 lb), respectively. At a wind speed of 31.3 m/s (70 mph) the wind dynamic pressure, q, has the value

$$q = 1/2\rho\,V^2 = 1/2\,(1.22)\,(31.3)^2 = 598\ \mathrm{N/m^2} \quad (7)$$

where ρ is the air density and V is the windspeed. For these values of W and q, Eqs. (4), (5), and (6) become:

$$P_{R_{64}} = \frac{2}{3}\left\{ [5995900 + 663698]^2 + [867616]^2 \right\}^{1/2} = 4477250\ \mathrm{N}\ (1006576\ \mathrm{lb}) \quad (8)$$

$$P_{R_{72}} = \frac{2}{3}\left\{ [8219900 + 808340]^2 + [1068860]^2 \right\}^{1/2} = 6060860\ \mathrm{N}\ (1362600\ \mathrm{lb}) \quad (9)$$

$$P_{A_{64}} = \frac{2}{3}\left[0.144\,(598)\frac{\pi}{4}(64)^2 \right] = 184680\ \mathrm{N}\ (41520\ \mathrm{lb}) \quad (10)$$

$$P_{A_{72}} = \frac{2}{3}\left[0.144\,(598)\frac{\pi}{4}(72)^2 \right] = 233733\ \mathrm{N}\ (52548\ \mathrm{lb}) \quad (11)$$

A comparison of the numbers in Eqs. (8) and (9) shows that the wind loading at 31.3 m/s is approximately 12% of the weight loading.

In order to compare the bearing applied loads to the rated static capacity, C_0, of the bearing, an equivalent load P_E is calculated in conformance with Ref. 2, which is:

$$P_E = 1.00\,P_R + 2.3\,P_A \quad (12)$$

Evaluating P_E for the two antenna sizes, there are obtained:

$$P_{E_{64}} = 4477250 + 2.3\,(184680) = 4902014\ \mathrm{N}\ (1102070\ \mathrm{lb}) \quad (13)$$

$$P_{E_{72}} = 6060860 + 2.3\,(233733) = 6598445\ \mathrm{N}\ (1483463\ \mathrm{lb}) \quad (14)$$

The rated static capacity, C_0, of the SKF 231/600 spherical roller bearing is 9,892,300 N (2,240,000 lb) per Ref. 1. The ratios between the static capacities and equivalent loads are as follows:

$$\frac{C_0}{P_{E_{64}}} = \frac{9892300}{4902014} = 2.018 \tag{15}$$

$$\frac{C_0}{P_{E_{72}}} = \frac{9892300}{6598445} = 1.499 \tag{16}$$

It should be recognized that the static capacity is that load which produces a permanent deformation less than 0.0001 times the diameter of the rolling element. The static load required to fracture the bearing is usually more than 8 C_0. From the standpoint of safety, the factor is very high, 1.5 × 8 or 12. Spherical roller bearings oftentimes operate at 2 or 4 times the C_0 value without there being any noticeable increase in the friction coefficient.

The basic bearing rating, C, is that load under which at least 90% of a large number of bearings will survive 1,000,000 rotations without any evidence of fatigue damage. For these elevation bearings the C value, from Ref. 1, is 7,695,000 N (1,730,000 lb). The ratios between the basic ratings and the equivalent loads are as follows:

$$\frac{C}{P_{E_{64}}} = \frac{7695000}{4902014} = 1.570 \tag{17}$$

$$\frac{C}{P_{E_{72}}} = \frac{7659000}{6598445} = 1.166 \tag{18}$$

The number of revolutions of the elevation bearings over a 50-year period might be approximately 60,000. Since this is a small portion of 1,000,000 rotations, on which the C factor is based, the probability of fatigue damage is extremely small. Bearing damage is much more likely to result from improper lubrication and corrosion than from being overloaded when used on the 70-m antenna.

Reference

1. SKF Industries, *SKF Spherical Roller Bearings Catalog*, 1960, Form 591-B/15M-773-SED.

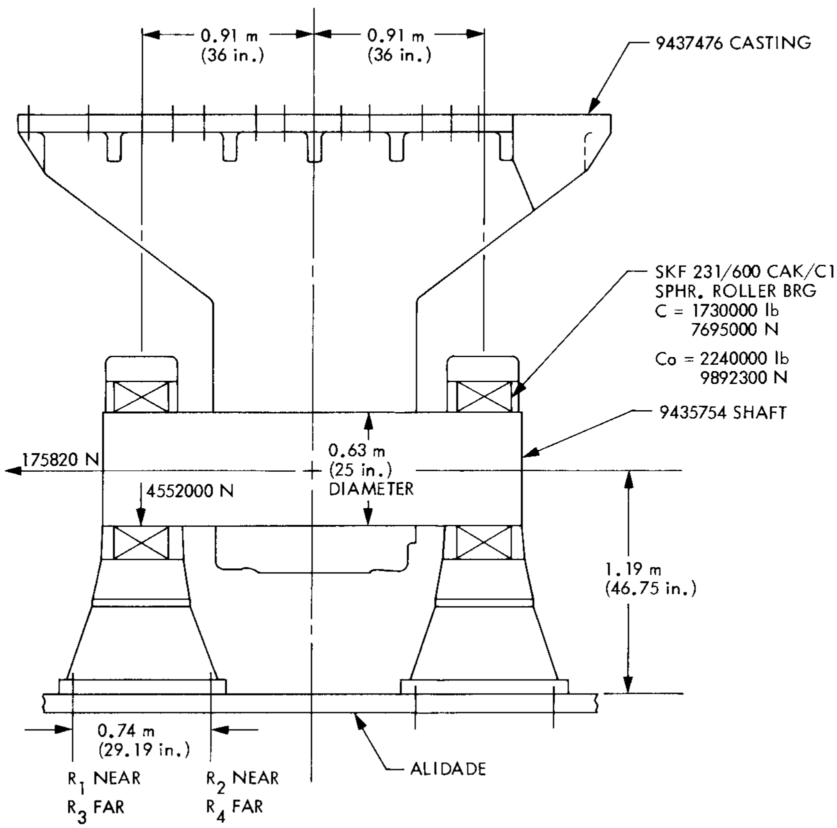

Fig. 1. Side view of elevation bearing installation

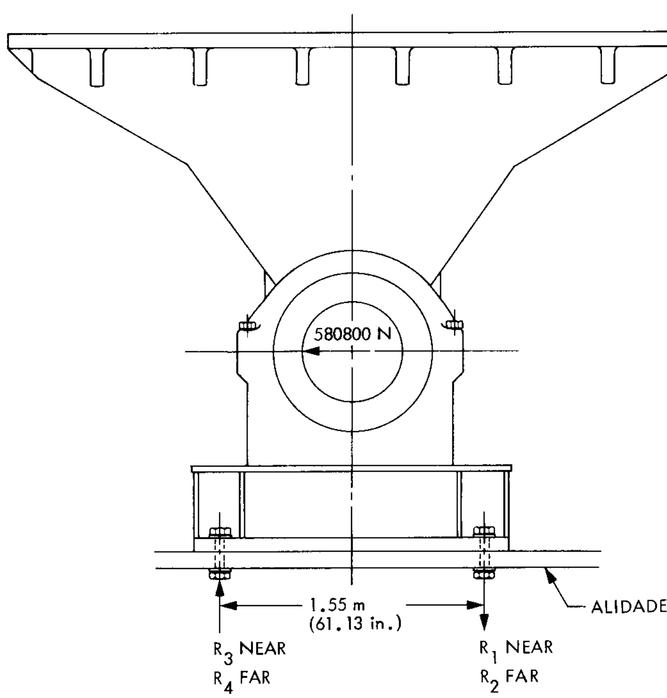

Fig. 2. End view of elevation bearing installation